The Post-Auricular Canal Hearing Aid: A Better Solution?

A Senior Honors Thesis

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by

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ABSTRACT

Hearing aid users face many problems and obstacles when choosing a particular style of hearing aid. Completely-in-the Canal (CIC) hearing aids provide significant acoustic benefit because the hearing aid delivers sound to a point very near the tympanic membrane (ear drum), resulting in high frequency amplification and a reduction of the occlusion effect that occurs when the ear canal is plugged. However, these styles can encounter maintenance problems due to a build up of cerumen (ear wax) in the hearing aid receiver. In addition to maintenance issues, the CIC cannot be worn by some hearing-impaired individuals because it cannot fit into the size and shape of their ear canals. A new style of hearing aid, called the SeboTek PAC, claims to provide the acoustic benefits of the CIC instrument without the drawbacks often encountered with the smaller CIC instruments.

This study was designed to test the effectiveness of the device, specifically as it relates to the manufacturer's claims of a reduction of the occlusion effect, optimal high frequency amplification, and increased speech understanding ability. It was expected that because the speaker portion of the PAC hearing aids fits deeply in the ear canal, the high frequency amplification, occlusion, speech recognition ability in quiet and noise, and perceived benefit obtained using the new device would be comparable to that obtained from CIC style hearing aids.

Ten adult subjects with high frequency sensorineural hearing loss were recruited for this study. The subjects were already fit with and wearing CIC or ITC (In-the-Canal) digital hearing aids. The subjects were seen in three visits spaced approximately 2 weeks apart. A routine hearing test was performed to ensure that the subject's hearing loss falls

within the fitting range of the new PAC hearing aid. Before being fit with the new hearing aid, the subject's performance with their current hearing aid was assessed using the California Consonant Test (CCT) (Owens & Schubert, 1977) to assess speech understanding in quiet, the Quick Speech in Noise (QSIN) Test (Killion et al., 2001) to measure the subject's ability to hear speech in noise, the measurement of gain and occlusion produced by the user's current hearing aids, and the subject's perception of performance with their current hearing aids using a questionnaire, the Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995). The subjects were then fit with the SeboTek PAC hearing aids and wore them for approximately 2 weeks. The performance of the subjects using the SeboTek hearing aids was then measured using the CCT and QSIN and measures on gain and occlusion. Results from the assessments for both hearing aid conditions were compared statistically to determine how the PAC style hearing aid compared to the subject's own hearing aids.

The results indicated no significant difference between the subjects' own hearing aids and the SeboTek PAC style hearing aids on measures of occlusion, speech understanding in quiet, speech understanding in noise, or perceived benefit. A significant difference in high frequency gain did exist, with the subjects' own hearing aids providing an average of 5 dB more gain than the SeboTek PAC style hearing aids. However, the significance of that finding for everyday living is questionable, given the lack of difference in the other measures of hearing aid performance.

For the limited number of subjects in this study, it was concluded that the SeboTek PAC style hearing aids would provide an acceptable alternative to the CIC style hearing aids and that future research on the device is warranted.

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CHAPTER 1

INTRODUCTION

Hearing aid styles have continuously evolved over the past 50 years. From the body-style hearing aids available in the mid-1900s, through the behind-the-ear style hearing aids that became available in the 1960s, and through the smaller and smaller custom instruments that were developed in the 1970s, 1980s and 1990s, an emphasis has been placed on reduction in size and visibility. Today, the smallest hearing aids available are the completely-in-the canal (CIC) style hearing aids, which are worn deep within the ear canal. Besides being very cosmetically appealing, CIC style hearing aids provide significant acoustic benefit because the hearing aid delivers sound to a point very near the tympanic membrane (ear drum). This results in excellent high frequency amplification (good amplification of the high-pitched sounds that are difficult for most individuals with hearing loss to hear). A deep fit in the ear canal leads to a reduction of the occlusion effect. The occlusion effect is caused by an increase in low frequency amplification and leads to the “head in a barrel sound” that you hear when your ear canal is plugged. (Greer, Clark & Martin, 2006)

Even though there are acoustic benefits from the CIC hearing aid, there are problems as well. For instance, the CIC cannot be worn by some hearing-impaired individuals because it cannot fit into the size and shape of their ear canals. Also, CICs routinely exhibit mechanical problems and break down because they are worn completely within the warm, moist environment of the ear canal and are constantly exposed to cerumen (ear wax).

One manufacturer, SeboTek, has developed a new hearing aid style, which they believe will provide many of the acoustic benefits of the CIC instrument (e.g., better high frequency amplification and reduced occlusion) without the drawbacks often encountered with the small CIC instrument (e.g., difficulty of fit and maintenance issues).

Hearing aids to date have incorporated the hearing aid speaker into the body of the device. SeboTek's new style of hearing aid consists of a small speaker component (which fits deeply in the ear canal) attached by a thin wire to a separate sound processor (which is worn behind the ear). Because the hearing aid is split into two parts, the part that is worn in the ear canal can be made smaller so that it fits comfortably deep into the ear canal of almost all individuals, providing good high frequency amplification and reduced occlusion. Moreover, the PAC style hearing aid is easier to repair if breakdowns occur; the speaker can be quickly replaced in the clinician's office rather than having to send the hearing aid in to the manufacturer for repair.

The manufacturer of the PAC style instrument claims that this new style of hearing aid has acoustic benefits similar to those obtained from CIC instruments. The purpose of this study is to investigate those claims. Because the speaker portion of the PAC hearing aid fits deeply in the ear canal, it is anticipated that the high frequency amplification, occlusion, speech recognition ability in quiet and noise, and perceived benefit obtained using the new device will be comparable to that obtained from CIC style hearing aids.

Even though the PAC style hearing aid sounds promising, its benefits are relatively untested. This study is designed to test the effectiveness of the device, specifically as it relates to the manufacturer's claims of a reduction of the occlusion effect, optimal high frequency amplification, and increased speech understanding ability. The specific research questions to be investigated are:

1. What is the size of the occlusion effect with the PAC style hearing aid as compared to the listener's current hearing aid?

2. What is the listener's speech recognition in quiet and in noise with the PAC style hearing aid as compared to the listener's current hearing aids?

3. How much high frequency amplification is provided by the PAC style hearing aid as compared to the listener's current hearing aid?

4. What is the perceived benefit from the PAC style hearing aid as compared to the listener's current hearing aid?

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Introduction

Every hearing aid is equipped with four basic circuitry components, which include a microphone, an amplifier, a receiver, and a battery. The hearing aid microphone picks up sound waves, or acoustic energy, in the air. The microphone converts these sound waves from acoustic energy to electrical energy. The electrical signal enters the amplifier which increases the intensity of the signal in proportion to the needs of the listener. The hearing aid receiver then converts the electrical signal back into acoustic energy because the ear does not process electrical signals. The battery of a hearing aid supplies power to the hearing aid and can vary in size depending upon the style of hearing aid. In general, the larger the battery, the longer it will last (DeBonis & Donohue, 2004).

2.2 Hearing Aid Styles

Even though all hearing aids are equipped with the same basic components, they come in different styles. The four most common styles are behind-the-ear, in-the-ear, in-the-canal, and completely-in-the-canal. Behind-the-ear (BTE) hearing aids, as the name suggests, are worn behind the ear and are connected to a hollow plastic hook which is connected to the plastic mold, custom made to fit in the individual's ear. The receiver, microphone and amplifier are all built into the same case (see Figure 2.1a). Batteries on behind-the-ear style hearing aids are relatively large which allows for longer wear between battery replacements (DeBonis & Donohue, 2004). BTEs can be used by patients with a mild to profound hearing loss, and are ideal for individuals with a high frequency hearing loss. About 31% of all hearing aid users wear BTE style hearing aids (Kirkwood, 2005).

In-the-ear (ITE) hearing aids are worn entirely in the concha and external auditory canal. The amplifier, microphone and receiver are all housed in a plastic case that is custom shaped using an impression of the user's ear (see Figure 2.1b). This style of hearing aid can typically be used by patients with mild to moderately-severe hearing losses. This style hearing aid is still able to utilize relatively large batteries. Approximately 38% of hearing aid wearers use ITEs, making this style the most popular.

In-the-canal (ITC) hearing aids fit entirely into the external auditory canal with a small protrusion into the concha(see Figure 2.1c). Like the ITE, the circuitry is built into a custom-molded plastic case of the ITC. However, in contrast, the ITC occupies the ear canal and only a part of the concha. About 19% of hearing aid users wear ITC style hearing aids.

Completely-in-the-canal (CIC) hearing aids are the smallest style of hearing aid. CIC aids are so small that they are barely noticeable in ears because they are inserted deep in the external auditory canal. The amplifier, microphone and receiver are all housed in the case of this instrument which is also custom fit in the listener's ear (see

Figure 2.1d). This style of hearing aid can be used for hearing losses that range from mild to moderate and are particularly well-suited to high frequency hearing losses. Because CICs are the smallest style of hearing aid, they require the smallest batteries, which must be changed often. Approximately 12% of hearing aid wearers use CIC style hearing aids.

Each hearing aid style comes with its advantages and disadvantages and clinicians work with their patients to choose the most appropriate style. There are multiple parameters to examine when determining the best fit for the patient. These include where the circuitry of the hearing aid is located on the device, comfort, cosmetic appeal, and battery size.

BTE hearing aids are able to achieve greater gain and maximum output because the microphone is separated from the receiver. Because the receiver and microphone are separated, feedback is less of an issue for behind-the-ear aids. This style of hearing aid is useful in background noise and can be worn by individuals with a mild to profound hearing loss. However, the size of the BTE aids makes this style cosmetically unappealing to some wearers.

In-the-ear hearing aids can be worn by individuals with most hearing losses. Full shell ITE aids are the largest of the in-the-ear styles and the half shell is the smaller version of the ITE aids. Although ITE aids are more cosmetically appealing to some over the BTE style, they are prone to feedback problems as the size of the hearing aid decreases because of the closer proximity of the microphone and receiver. Feedback can be reduced by creating an ear piece that is tightly sealed and by positioning the microphone as far from the receiver as possible.

In-the-canal hearing aids require smaller batteries and are not appropriate for all hearing losses because of the limit to their power. ITC aids are cosmetically appealing to some because of their discreetness, but they are prone to mechanical problems due to the amount of moisture and cerumen they are exposed to. This instrument is also prone to feedback issues, again due to the proximity of the microphone and receiver.

Completely-in-the-canal hearing aids are very cosmetically appealing because of their small size and discreetness. CIC style hearing aids provide increases in the usable gain and provide significant acoustic benefits because the hearing aid delivers the sound closer to the tympanic membrane, maximizing high frequency amplification. The outer part of the ear, or pinna, provides amplification for the ear and because this style of hearing aid does not obstruct the pinna it allows for the natural acoustic benefits of the ear canal and concha to occur. The result is an increased amplification of high frequency sounds. Another advantage of the deep fit is a reduction of the occlusion effect. Because CICs fit deeply in the ear canal, there is a decrease in bone-conducted signals and vibrations that create “hollow” quality to speech (Mueller & Ebinger, 1996).

There are also disadvantages to the CIC style hearing aid. The CIC cannot by worn by all hearing-impaired individuals because it cannot fit into the size and shape of their external auditory canals. Because of the size of the CIC style hearing aids directional microphones cannot be incorporated. The benefits of directional microphones include improved signal-in-noise ratios. Like the ITC style of hearing aids, CICs exhibit mechanical problems and break down because they are worn completely within the warm, moist environment of the ear canal and are constantly exposed to cerumen (Greer, Clark & Martin, 2006).

2.3 “Newer” Hearing Aid Styles

Recently, new styles of hearing aids have been introduced to the market. One new style is an open fitting hearing aid, like *Resound Air*. Open fit hearing aids have a mini behind-the-ear style case, which like the BTE includes the microphone, amplifier, receiver, and battery. They differ from a typical BTE because attached to the end of the tube is a small silicone tip that is designed to reduce the occlusion effect by leaving the ear canal open (see Figure 2.2). This style of hearing aid amplifies hard-to-hear high frequency sounds while allowing other sounds to still enter the ear normally (http://www.resoundair.com/micro/consumer/listenning.htm).

Yet another variation of the BTE is the *Vivatone*. In this style a mini BTE case containing the microphone, amplifier, and battery is worn behind the ear, but the receiver portion is fit deeply in the ear canal (see Figure 2.3). The intent of this style of hearing aid is to allow natural sounds into the canal while still amplifying those sounds that are difficult for the patient to hear. These instruments also claim to reduce feedback by separating the microphone and receiver and the occlusion effect by leaving the ear canal open. This style is recommended for individuals with a mild to moderate hearing loss (http://www.vivatone.com/index.html).

A final variation on the BTE style can be found in the SeboTek hearing aid. Like the Vivatone style hearing aid, a mini BTE case containing the microphone, amplifier, and battery is worn behind the ear. Also like the Vivatone, the receiver portion is separate and fits down in the ear canal (see Figure 2.4). However, in the case of the SeboTek instrument, the receiver portion is meant to fit into the bony portion of the ear canal, completely occluding the canal, much like a CIC. SeboTek intentionally blocks the ear canal, unlike the open-fitting hearing aids, because the manufacturers believe that the ear canal needs to be completely blocked in order for the directional microphone to work effectively. A deep fit also allows for a good high frequency amplification and reduced occlusion effect. Because this hearing aid is split into two parts, it is easier to repair if breakdowns should occur. The speaker can quickly and easily be replaced in a clinician's office instead of being sent to the manufacturer for repairs (http://www.sebotek.com/).

Manufacturers of each of these new style hearing aids claim that they reduce occlusion effect, allow for optimal high frequency amplification, increase the signal-to-noise ratio, and enhance speech understanding ability. Although these new styles of hearing aids sound promising, the benefits and disadvantages of each are relatively untested.

2.4 Measures of Hearing Aid Performance

In order to determine the success of a hearing aid fitting, measures of hearing aid performance must be conducted. These measures can range from measures of real ear gain and occlusion, to measures of the subject's speech understanding in quiet and in noise, to measures of the subject's perception of his or her own performance with the hearing aid. Several such measures were completed for this thesis, and each is described below.

Probe Microphone Measures. A probe microphone system can be used to measure the sound pressure a hearing aid generates in the subject's ear canal. The test is performed by placing a probe microphone near the tympanic membrane. The measurement is done by first measuring the level of sound in the canal without the hearing aid in place. This is called the real ear unaided response (REUR). This measurment provides information on the resonance characteristics of the ear canal and concha. The real ear aided response (REAR) is then measured with the hearing aid inserted on the subject and turned on. The REAR expresses the decibel level (in dB SPL) generated by the hearing aid in the ear canal. The REAR shows how well the hearing aid is working for the user by comparing it to the REUR. Specifically, the REUR is subtracted from the REAR to determine the real ear insertion response (REIR), which shows the gain of the hearing aid across frequency (Mueller, Hawkins & Northern, 1992).

A probe microphone system can also be used to measure the occlusion effect. The occlusion effect is caused by excess low frequency amplification and leads to the "head in a barrel sound" that can be heard when your ear canal is plugged (as it typically is with a hearing aid). Occlusion occurs at frequencies of 1000 Hz or less and is the result of the increase in sound-pressure level (SPL) in the external ear canal when the outer ear is covered or blocked. (Greer Clark & Martin, 2006).

To measure the occlusion effect with a probe microphone system, a small probe is first inserted into the subject's unoccluded ear (i.e. without the hearing aid). The subject is instructed to vocalize a vowel "ee" with a consistent level around 60 dBSPL. The probe microphone is placed near the tympanic membrane and records it as the "unaided" response. The hearing aid is then inserted and the subject again vocalizes the vowel "ee." The probe microphone now measures the "aided" response. The decibel difference between the unoccluded and the occluded tests are calculated and displayed in a curve which reveals the extent of the occlusion effect as a function of frequency (MacKenzie & Mueller, 2004).

Tests of Speech Understanding. Many tests have been developed to determine a person's ability to understand speech. There are a variety of types of tests that use sentences, words, nonsense syllables and speech-in-noise to find valuable information about the subject's word recognition ability. Two different tests were used in this thesis. One test, the California Consonant Test (CCT) was designed by Owens and Schubert in 1977 for individuals with high-frequency hearing losses. Each list of 50 target words is presented in a closed set (multiple choice) format, with three incorrect choices. For example, the target word "beach" would be presented, and the subject would have to check that word from among the following four choices "beet, beep, beach, beak." A sample CCT list is presented in Appendix A. This test was chosen because subjects with high-frequency hearing loss, such as those who participated in this study, often have trouble with this test because they are unable to differentiate consonants whose energy is concentrated in high frequencies (DeBonis & Donohue, 2004).

The second test that was included in this thesis is the Quick SIN (QSIN) test. The purpose of the QSIN is to determine the subject's signal-to-noise ratio loss (Niquette, Revit & Skinner, 2001). This test was chosen because it is a commonly used clinical test, which can be completed in a short period of time. For this test, subjects listen to 6 sentences, each sentence at a progressively more difficult signal-to-noise ratio. The number of target words correctly identified in each sentence is determined and used to calculate the signal-to-noise ratio needed for 50% performance. Differences between the signal-to-noise ratios needed for 50% performance indicate different hearing in noise abilities; subjects who hear well in noise will need relatively low signal-to-noise ratios to achieve 50%, while subjects who hear poorly in noise will need higher signal-to-noise ratios to achieve 50%.

Subjective Measures of Hearing Aid Performance. Subjective measures of hearing aid performance are those that use the subject's opinion or perception of how the subjects do with the hearing aid. Often these measures are in the form of a questionnaire. Subjective measures are needed because often individuals can detect subtle differences that cannot be measured with objective tests or on speech understanding tests given in a clinic. The Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995) is a questionnaire designed to measure the benefit a subject perceives a hearing aid to have. The APHAB was chosen because it is the questionnaire of choice for many audiologists in clinical practice. The benefits of the hearing aids are determined by comparing the subject's perception of how they do unaided to how they do with a hearing aid. Alternatively, the benefit of a new hearing aid can be determined by comparing the subject's perception of the previous hearing aid to the new hearing aid.

2.5 Summary

The manufacturer of the SeboTek PAC style instrument claims that this new style of hearing aid has acoustic benefits similar to those obtained from CIC instruments. The purpose of this study is to investigate those claims. This study is significant because the PAC hearing aid style is new to the market and relatively untested. If it can be shown that the PAC hearing aid style provides benefits comparable to that obtained from the CIC style hearing aid, clinicians would have more confidence in recommending this new style to their patients who have been unable to wear CIC style hearing aids because of fit or repair problems.

The specific research questions to be investigated are:

1. What is the size of the occlusion effect with the PAC style hearing aid as compared to the listener's current hearing aid?

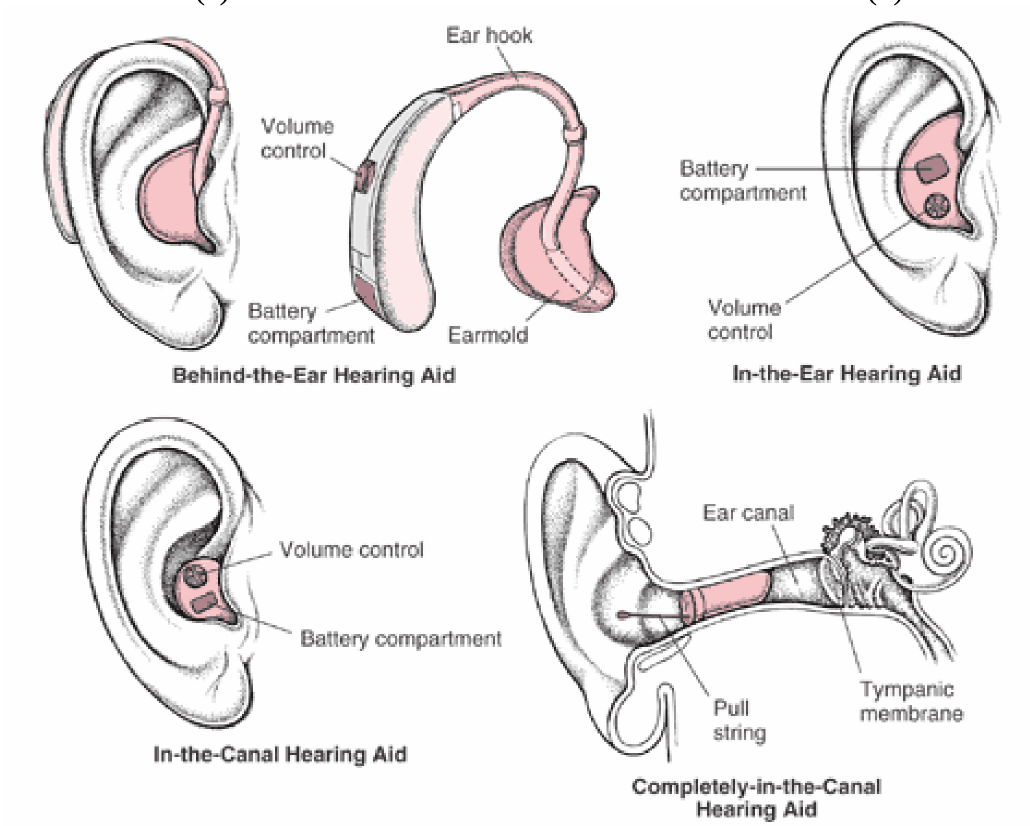
2. What is the listener's speech recognition in quiet and in noise with the PAC style hearing aid as compared to the listener's current hearing aids?

3. How much high frequency amplification is provided by the PAC style hearing aid as compared to the listener's current hearing aid?

4. What is the perceived benefit from the PAC style hearing aid as compared to the listener's current hearing aid?

Figure 2.1

(a) (b)



(c) (d)

Figure 2.2

Figure 2.3

Figure 2.4

CHAPTER 3

METHODS

The purpose of this study was to determine the size of the occlusion effect with the SeboTek PAC style hearing aids as compared to the subject's current hearing aid, to find how the listener's speech recognition in quiet and in noise with the PAC style hearing aid compares to the listener's current hearing aids, to measure how much high frequency amplification is provided by the PAC style hearing aid as compared to the listener's current hearing aid, and finally to determine the patient's perceived benefit from the PAC style hearing aid as compared to the listener's current hearing aid.

3.1 Subjects

Ten adults with sensorineural hearing loss who were already fit with digital CIC or ITC hearing aids were recruited for this study using the Speech and Hearing Clinic database (See Appendix B for the Informed Consent, and Appendix C or the Recruitment letter). The audiometric data for the ten subjects is presented in Appendix E. The subjects were offered a small payment of $15 per visit plus $2 reimbursement for parking.

3.2 Procedure

The subjects were seen over a course of three visits each, lasting approximately one hour. At the first visit, consent was obtained from the individuals and they were then asked to complete a short questionnaire about their perception of performance with their own hearing aids. Following the questionnaire, the subjects were given a standard audiological evaluation to ascertain the type, degree, and configuration of their hearing loss. The subjects then completed assessments of their speech understanding ability in quiet and in noise. At the second visit, the subjects were fit with the new PAC style hearing aids. Using a probe microphone system the occlusion effect was tested with the listener’s current hearing aids and the SeboTek PAC style of hearing aids. The gain of the subject’s current hearing aid and the PAC style hearing aid were measured using the probe microphone system using standard clinical procedures (Mueller, 1992). The subjects were asked to wear the new style of hearing aids for two weeks and on their third visit they were asked to assess the perception of the hearing aid’s performance using the same short questionnaire given to them at the first visit. Finally, speech understanding ability in quiet and in noise was assessed with the patient wearing the PAC style aids.

3.3 Questionnaire

The subject’s perception of performance with his or her current hearing aids, and after wearing the SeboTek PAC hearing aid was assessed using a questionnaire, the Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995). The questionnaire is shown in Appendix D. The information collected was used to help the researcher understand the patient's perceived benefits from the subject's own digital hearing aids and the SeboTek PAC style hearing aids. A repeated measures analyses of variance was used to compare the patients' perceived benefit from their own hearing aids and the perceived benefit from the PAC style hearing aids.

3.4 Audiological Evaluation

The audiological evaluation consisted of an otoscopy, pure tone air and bone conduction testing (masking when needed), and measurement of speech recognition thresholds (SRT). All testing was completed using standard clinical procedures. The evaluation was performed to ensure that the subject's hearing loss fell within the fitting range of the new PAC hearing aid and so that the hearing aid could be programmed appropriately. The audiometric data for the subjects can be found in Appendix E.

3.5 Tests of Speech Understanding Ability

California Consonant Test (CCT) (Owens & Schubert, 1977) The CCT was presented at 50 dB HL from a speaker located in front of the patient (0 degrees azimuth). The test consists of 50 target words that are presented in a closed set. The subjects had a list of four possible choices for each test item, and they were asked to mark their choice after each of the 50 items and a percent correct score was assigned. The percent correct scores were arc-sin transformed to stabilize the error variance (Studebarker, 1985). A t-test was then used to test for a significant difference between the scores obtained with the patients' own hearing aid and with the PAC style hearing aid. A sample CCT word list can be found in Appendix A.

Quick Speech in Noise Test (QSIN) (Niquette, Revit & Skinner, 2001) Hearing aid performance in noise for both hearing aids was tested using the QSIN. For each test, subjects heard six sentences in multi-talker babble and were asked to repeat the sentences back. The sentences were presented at 50 dB HL through the front speaker (0 degrees azimuth) and the speech babble was presented through the rear speaker (180 degrees azimuth) starting at 25 dB HL, resulting in a signal-to-noise ratio (S/N) of +25 dB. As the test progressed, the level of the speech babble increased in 5 dB steps (i.e., 30 dB HL, 35 dB HL, 40 dB HL, 45 dB HL, 50 dB HL). The tests were given twice for each subject, as is standard in clinical practice. The signal-to-noise ratio loss is determined by subtracting the total number of words that were repeated correctly by the subjects from the standard score of 25.5[1]. The typical, normal hearing person requires a +2 dB SNR to hear 50% of the words correctly (i.e. SNR 50= 2 dB). Sample test lists can be found in Appendix F. A t-test was used to determine whether or not a significant difference existed between the subjects' own hearing aids and the PAC style hearing aids.

3.6 Probe Microphone Measurements

Probe microphone measures of hearing aid gain Real ear unaided responses and aided responses, with both sets of hearing aids, were measured by placing a small microphone in the subjects' ear canals and presenting tones at soft (50 dB SPL), moderate (60 0r 65 dB SPL), and loud intensity (80 dB SPL) levels with a swept pure tone signal. Because of some inconsistency in the number of levels measured for each

[1] The 25.5 value is a result of the Tillman and Olsen (1973) method of estimating the 50% point on the psychometric function: highest SNR + ½ step size - # of correct responses = 25 + 2.5 - # of correct responses = 27.5 - # of correct responses. In order to calculate SNR loss, 2 dB is subtracted from 27.5 dB to give the 25.5 dB value.

patient and each ear, data were only analyzed for moderate inputs (60 or 65 dB SPL) for the right ear in 8 out of 10 subjects. The left ear was used for two of the subjects. A paired samples t-test was used to determine whether or not a significant difference in hearing aid gain existed between the subjects' own hearing aids and the PAC style hearing aids.

Occlusion Effect To measure the size of the occlusion effect, the subject was asked to vocalize at a level of approximately 60 dB SPL (the patient was able to see the sound level meter to monitor the level while a probe microphone measured the level of sound in the ear canal). This was conducted under two conditions: 1) occluded with the current hearing aid in place and 2) occluded with the SeboTek PAC hearing aid in place. A repeated measures ANOVA was used to examine the occlusion effect under the two different conditions.

CHAPTER 4

RESULTS AND DISCUSSION

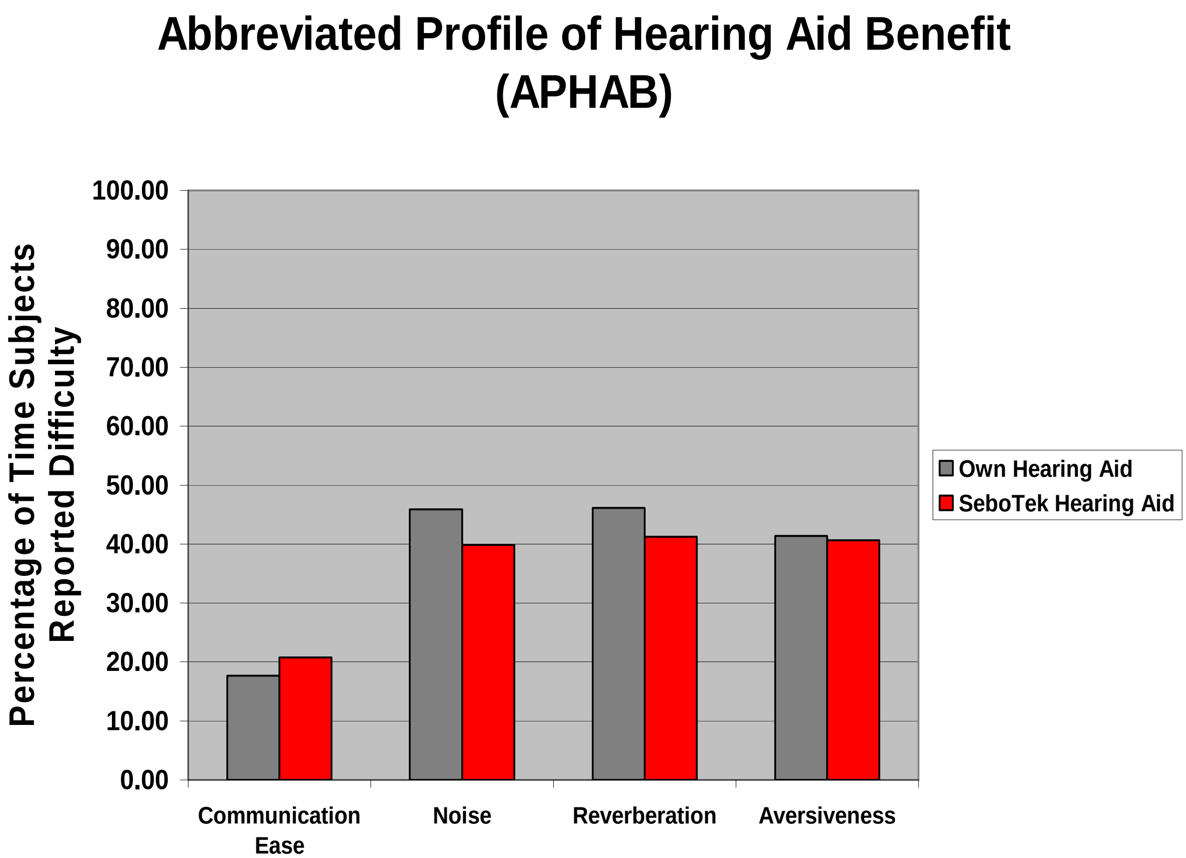
As stated in Chapter 3, the purpose of this study was to find how the listener's speech recognition in quiet and in noise with the PAC style hearing aid as compared to the listener's current hearing aids, to measure how much high frequency amplification is provided by the PAC style hearing aid as compared to the listener's current hearing aid, to determine the size of the occlusion effect with the SeboTek PAC style hearing aids as compared to the subject's current hearing aid, to, and finally to determine the patient's perceived benefit from the PAC style hearing aid as compared to the listener's current hearing aid. The results from each of these assessments will be described, analyzed, and discussed in greater detail in this chapter.

4.1 Abbreviated Profile of Hearing Aid Benefit

Figure 4.1 illustrates the subjects' mean perceived benefit from the two styles of hearing aids as measured using the Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995). The individual results for the subjects can be found in Appendix G. As can be seen in the graph, there do not appear to be any noteworthy differences between the perceived benefit from the subject's own hearing aids compared to the perceived benefit from the SeboTek hearing aids for any of the four subscales.

A repeated measures two-way Analysis of Variance (ANOVA) (with within-subjects factors of "hearing aid type" and "APHAB subscale") indicated no significant difference for the main effect of hearing aid type ($F[1,9] = .17$, $p = 0.69$). This finding suggests that the subjects in the present study achieved about equal benefit from both sets of hearing aids. The analysis did indicated a significant difference for the main effect of APHAB subscale ($F[3,7] = 6.98$, $p = 0.02$), suggesting that subjects found the hearing aids to be more beneficial in some situations than in others. Post hoc comparisons of the subscale means found no significant differences between the BN (Background Noise), RV (Reverberation), and AV (Aversiveness) subscales, but that the scores obtained on the EC (Ease of Communication) subscale were significantly different from each of the others. There was no significant interaction between hearing aid type and APHAB subscale ($F[3,7] = 1.220$, $p = 0.371$), suggesting that difference in scores across subscales was not related to the type of hearing aid worn.

Figure 4.1

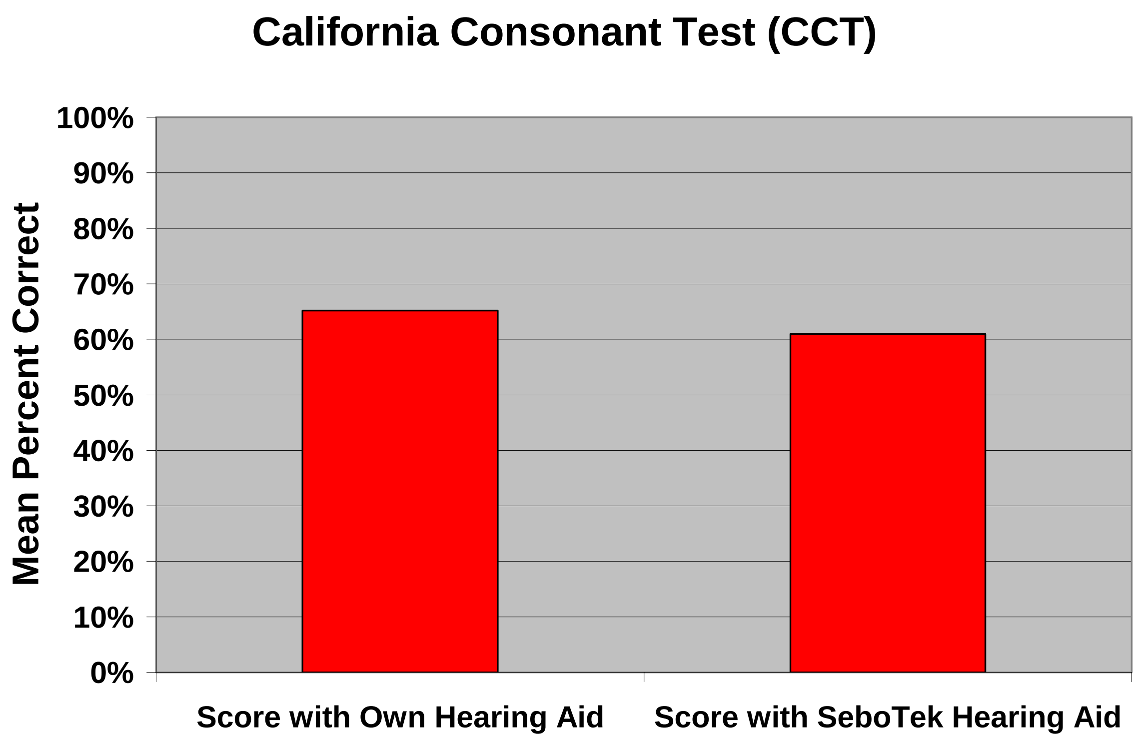


4.2 California Consonant Test

Figure 4.2 illustrates the mean percent correct score obtained on the California Consonant Test (CCT) (Owens & Schubert, 1977) when presented to the subjects in quiet wearing their own hearing aids and the SeboTek hearing aids. Individual results are given in Appendix H. The results show that the subjects performed about equally with the SeboTek aids as compared to their performance with their own hearing aids.

The percent correct scores were arcsin transformed to stabilize the error variance (Studebaker, 1985) before statistical analysis. A paired-samples t-test indicated no significant difference in the arcsin transformed scores, $t(9) = 1.30$, $p = 0.23$ (two-tailed), suggesting that both the subjects' own hearing aids and the SeboTek hearing aids provide similar amplification of high frequency words in quiet.

Figure 4.2

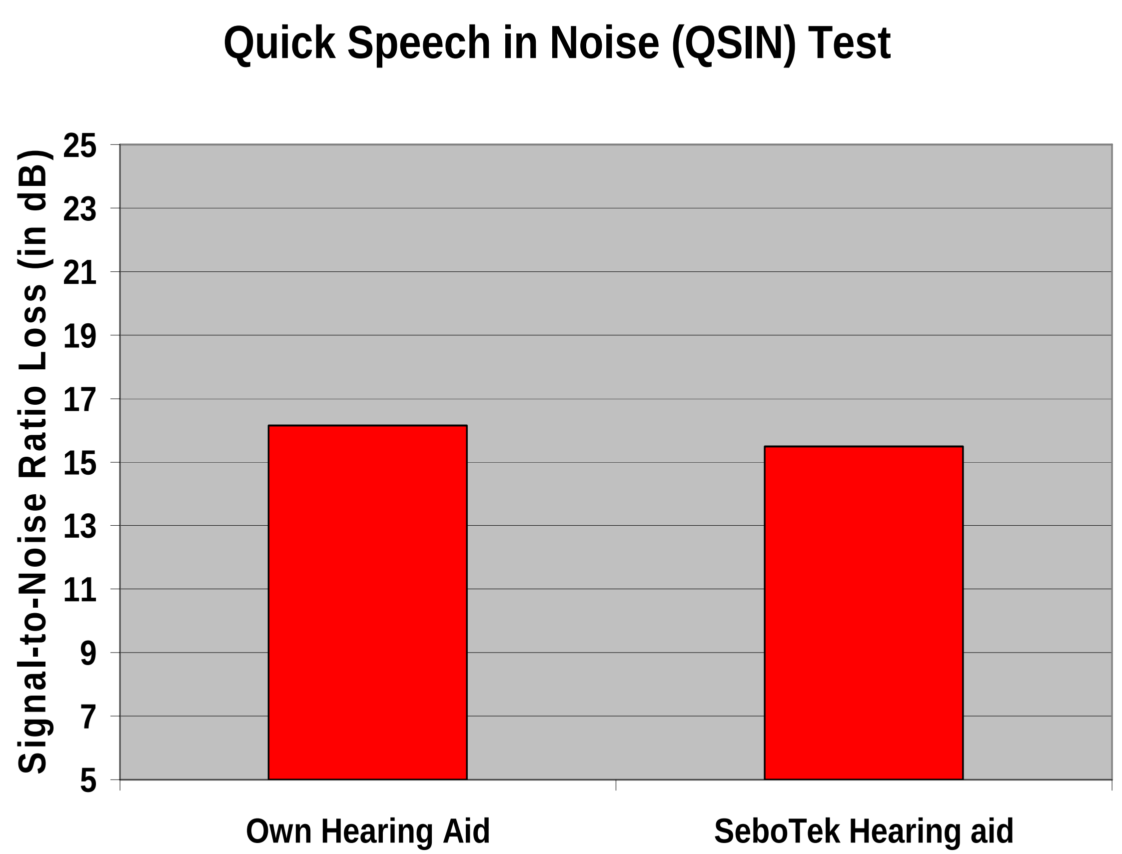


4.3 Quick Speech in Noise Test

Figure 4.3 shows the mean signal-to-noise ratio (S/N) loss of the test subjects when wearing their own hearing aids and the SeboTek hearing aids. Individual subject results are shown in Appendix I. The results indicate that the average signal-to-noise ratio loss was about the same for both types of hearing aids

A paired-samples t-test indicated no significant difference in the S/N loss measured while wearing the two sets of hearing aids, $t(9) = 0.31$, $p = 0.76$ (two-tailed), indicating that both sets of hearing aids performed equally well for listening in background noise. It is important to note that in the case of this speech test, a lower score is better because the signal-to-noise loss is being measured.

Figure 4.3



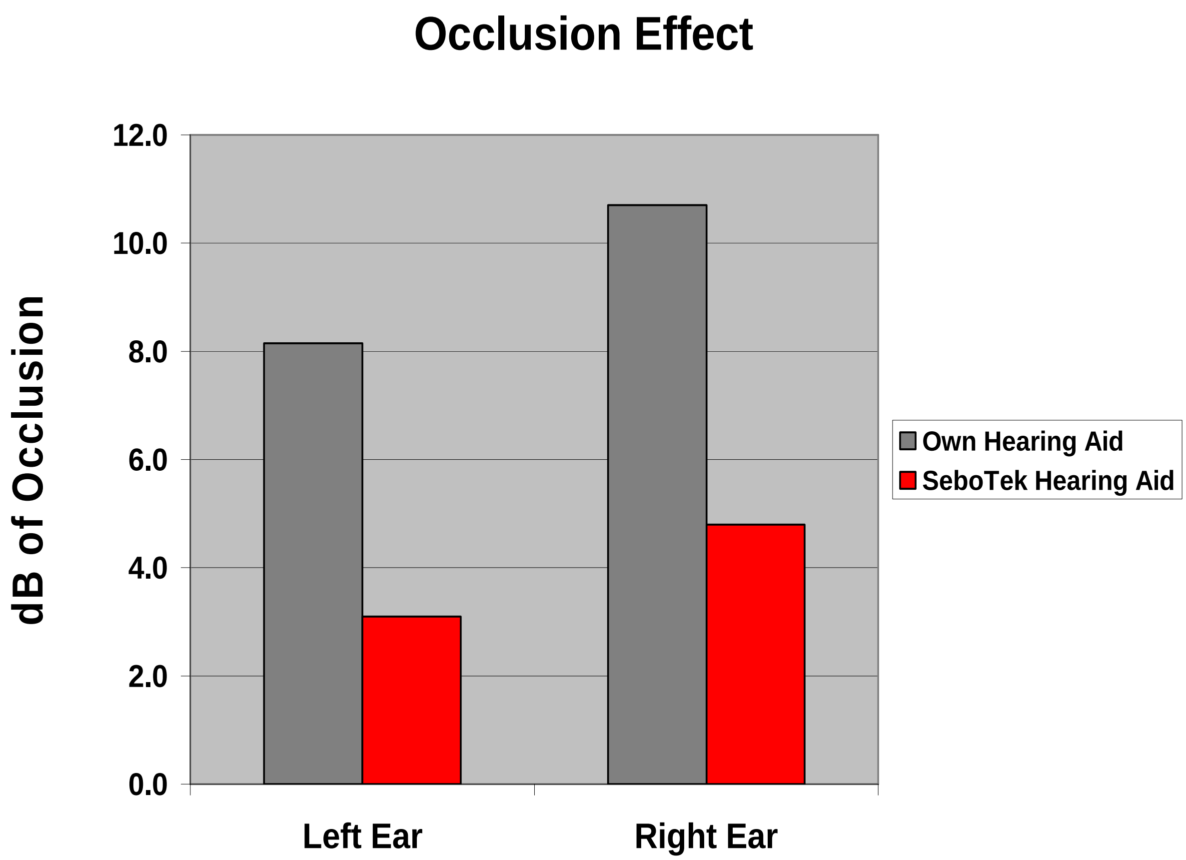
4.4 Occlusion Effect

Figure 4.5 illustrates the mean occlusion effect measured when the patients were wearing their own hearing aids and when fit with the SeboTek hearing aids. Results are shown for the right and left ears separately. As can be seen, the mean occlusion effect appears to be reduced by about 5 dB when wearing the SeboTek hearing aids.

A repeated measures two-way ANOVA (with within-subjects factors of “hearing aid type” and “test ear”) indicated no significant difference for the main effect of hearing aid type ($F[1,8] = 3.86$, $p = .085$). The analysis also indicated no significant difference for the main effect of test ear ($F[1,8] = 0.73$, $p = .42$) and no significant interaction between hearing aid type and test ear ($F[1,8] = 0.37$, $p = .85$). These findings indicate that both sets of hearing aids result in equivalent occlusion, regardless of ear.

Even though the SeboTek hearing aids appeared to produce slightly less occlusion in Figure 4.5, the differences were not large enough to be considered statistically significant. Appendix J shows the data for the individual subjects. As can be seen eight out of ten subjects demonstrated lower occlusion effects when wearing the SeboTek hearing aid. However, the size of the occlusion effect was highly variable across subjects. This variability is likely responsible for the lack of significant difference between hearing aid type. So, even though the statistics did not show a significant difference, the data for the individual subjects show some support for SeboTek’s claim for reduced occlusion.

Figure 4.4



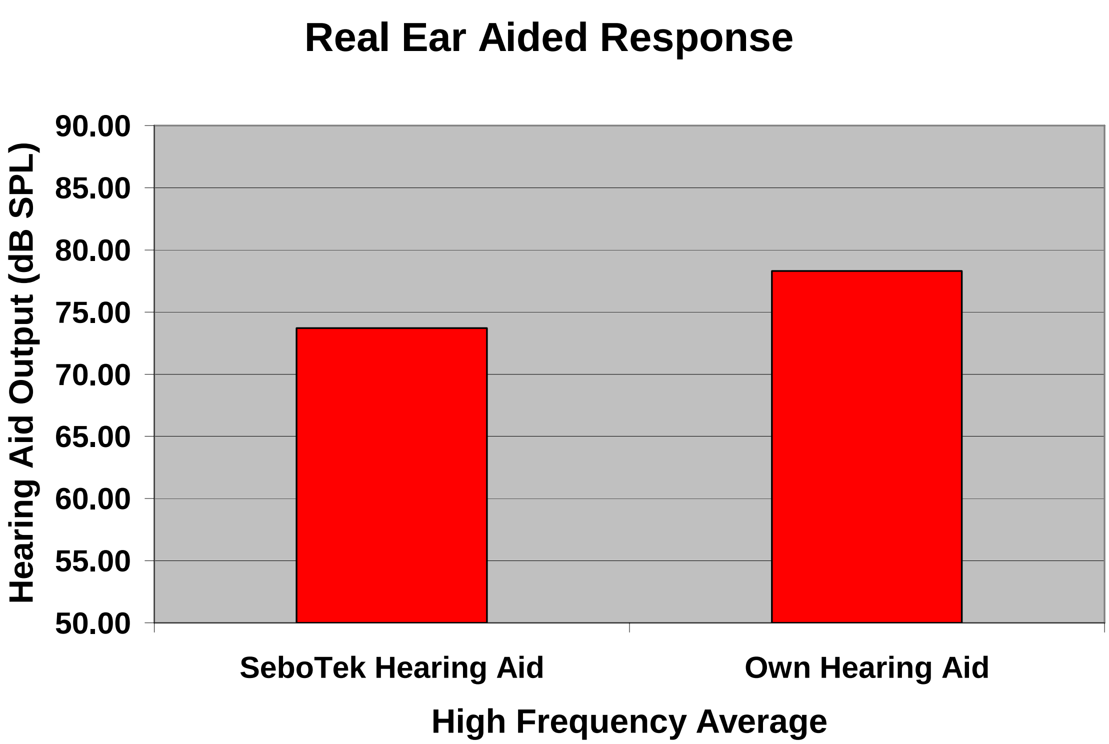
4.5 Real Ear Aided Response

Figure 4.4 shows the mean high frequency average (HFA) real ear aided response for the subjects' right ears when fit with their own hearing aids and with the SeboTek instruments. The individual results for the subjects can be found in Appendix K. The average results show that subjects received approximately 5 dB more gain from their own hearing aids that from the SeboTek hearing aids. It is noteworthy that 8 out of 10 of the individuals acquired more gain from their own hearing aids than from the PAC style hearing aids.

A paired-samples t-test indicated a significant difference in high frequency average gain, $t(9) = -2.27$, $p = .05$ (two-tailed), indicating that the subjects' own hearing aids provided significantly more gain than the SeboTek hearing aids.

Although the results of this particular test were found to be statistically significant, they might not be clinically significant. The analyses described above found no significant difference in the subjects' ability to understand speech in quiet (see Figure 4.2), in noise (see Figure 4.3), or in perceived benefit from the hearing aids (see Figure 4.1), suggesting that the difference in hearing aid gain may not be meaningful to daily life.

Figure 4.5



4.6 Anecdotal Observations

The study found that, on average, the subjects performed equally as well on measures of speech understanding in quiet, in noise, occlusion, and perception of benefit with the SeboTek PAC style hearing aids and the subjects' own hearing aids. Individual fittings and feedback from each of the subjects provided additional information on the fit and performance of the PAC style hearing aid. Several such observations are noted below.

Fitting issues were encountered with three or four of the subjects due to the lack of experience with fitting this particular style of hearing aid. As a result, feedback from the SeboTek PAC hearing aids occurred with those individuals, creating mild annoyance and programming problems. For one or two of the subjects, the PAC style hearing aid was difficult to fit because the size of the subjects' ear canals was slightly smaller than the smallest size tip that the PAC instrument could be fit with (7mm). This may suggest that the PAC style hearing aid is not appropriate for all individuals and a smaller size tip may be beneficial.

One individual in the study enjoyed his experience with the PAC style hearing aid so much that he wanted to purchase the instruments. It was found that his individual results reflected the averages that were found for each of the tests. There were no subjects in the study who completely disliked the SeboTek PAC style hearing aids; although two or three noted that they prefer their own current digital technology to the PAC style instruments. This may be a result of the short period of time the subjects were asked to wear the hearing aids, not allowing for them to acclimate to the new instruments.

Although the PAC style hearing aid performed equally as well on most measures, a second appointment following the SeboTek PAC hearing aid fitting would have been beneficial to the subjects in order to fine tune the instruments. A follow-up appointment would have been useful to make to the PAC style instruments perform at the optimal level for the subjects in this study.

CHAPTER 5

SUMMARY AND CONCLUSIONS

As previously stated, the purpose of this study was to determine if the SeboTek PAC style hearing aid provided benefits similar to those typically seen with the CIC style hearing aids. To that end, measurements were made of each subject's high frequency amplification, speech understanding in quiet and noise, occlusion, and perception of benefit with both their own hearing aids and with the SeboTek PAC style hearing aid.

The study found that both hearing aid styles performed equally well on measures of speech understanding in quiet, as measured using the CCT (Owens & Schubert, 1977), in noise as measured using the QSIN (Niquette, Revit & Skinner, 2001), occlusion, and perceived benefit as determined by the results of the APHAB (Cox & Alexander, 1995).

The subjects did, however, achieve significantly more high frequency gain using their own hearing aids compared to the SeboTek PAC style aids (recall that a mean advantage of 5 dB was noted). But, given that the subjects performed equally well on measures of speech understanding ability in quiet and in noise and that the subjects perceived both hearing aid styles to provide similar benefit, one must wonder if the 5 dB advantage provided by the subjects' own hearing aid has much of a practical effect on the everyday life.

The styles of hearing aids have drastically changed over the past 50 years. The new technology that is on the market may allow hearing-impaired individuals who can not use CIC instruments (because of degree of hearing loss, irregularly shaped ear canals, or frustration with frequent repairs) to wear discreet instruments that provide acoustic benefits that are comparable to that of current CIC technology. For the subjects in this study, the SeboTek PAC style hearing aids would seem to be an acceptable alternative to the more conventional digital hearing aids technology such as the CIC and ITC hearing aids. Although more research needs to be conducted on the SeboTek PAC style hearing aids, this study allows clinicians to feel comfortable in recommending a trial period with the SeboTek PAC style hearing aids, particularly for patients who cannot wear CIC style hearing aids.

APPENDIX A

SAMPLE CALIFORNIA CONSONANT TEST LIST

CALIFORNIA CONSONANT TEST

Name ______________________________ Date ____________________

List 1

Sample Items

1	BACK ___	BAG ___	BATCH ___	BATH ___
2	RICE ___	DICE ___	NICE ___	LICE ___
3	SEEN ___	SEED ___	SEAL ___	SEAT ___
4	BAIL ___	TALE ___	SAIL ___	DALE ___
5	LEAVE ___	LEASH ___	LEAN ___	LEAGUE ___
6	RAIL ___	JAIL ___	TAIL ___	BALE ___

Test Items

1	GAVE ___	GAME ___	GAZE ___	GAGE ___
2	PAIL ___	SAIL ___	FAIL ___	TAIL ___
3	CUFF ___	CUP ___	CUSS ___	CUT ___
4	MUSS ___	MUCH ___	MUSH ___	MUFF ___
5	FAKE ___	FATE ___	FACE ___	FAITH ___
6	TILL ___	CHILL ___	PILL ___	KILL ___
7	LEASE ___	LEASH ___	LEAF ___	LEAP ___
8	SEEP ___	CHEAP ___	SHEEP ___	HEAP ___
9	FACE ___	FAITH ___	FATE ___	FAKE ___
10	BAYS ___	BABE ___	BALE ___	BATHE ___
11	PAGE ___	PAID ___	PAYS ___	PAVE ___
12	KICK ___	PICK ___	TICK ___	THICK ___
13	LAUGH ___	LASH ___	LASS ___	LAP ___
14	SHEEP ___	SEEP ___	CHEAP ___	HEAP ___
15	GAVE ___	GAME ___	GAGE ___	GAZE ___
16	BEACH ___	BEEP ___	BEAK ___	BEET ___
17	MASS ___	MAP ___	MAT ___	MATH ___
18	PATH ___	PATCH ___	PACK ___	PAT ___
19	GAZE ___	GAGE ___	GAVE ___	GAME ___
20	SICK ___	CHICK ___	THICK ___	TICK ___
21	SHIN ___	SIN ___	THIN ___	CHIN ___
22	MUFF ___	MUCH ___	MUSH ___	MUSS ___
23	REACH ___	REAP ___	REEF ___	REEK ___
24	BACK ___	BAT ___	BATCH ___	BATH ___
25	TAME ___	SHAME ___	FAME ___	SAME ___
26	CORE ___	PORE ___	TORE ___	SORE ___
27	RAGE ___	RAISE ___	RAVE ___	RAID ___
28	FILL ___	PILL ___	KILL ___	TILL ___
29	CHOP ___	POP ___	TOP ___	SHOP ___
30	MUCK ___	MUTT ___	MUSS ___	MUFF ___
31	VALE ___	DALE ___	JAIL ___	BALE ___
32	PEACH ___	PEAT ___	PEAK ___	PEEP ___
33	RACK ___	RASH ___	RAT ___	RAP ___
34	HAG ___	HAD ___	HAVE ___	HAS ___
35	TICK ___	SICK ___	THICK ___	PICK ___
36	CHAIR ___	CARE ___	SHARE ___	FAIR ___
37	BEACH ___	BEAK ___	BEET ___	BEEP ___
38	BEAK ___	BEEP ___	BEAT ___	BEEF ___
39	CHEEK ___	CHIEF ___	CHEAT ___	CHEAP ___
40	CUP ___	CUT ___	CUSS ___	CUFF ___
41	KIT ___	KICK ___	KISS ___	KID ___
42	PIN ___	KIN ___	TIN ___	THIN ___
43	BUS ___	BUT ___	BUCK ___	BUFF ___
44	GATE ___	BAIT ___	DATE ___	WAIT ___
45	LAUGH ___	LASS ___	LASH ___	LAP ___
46	HIP ___	HIT ___	HISS ___	HITCH ___
47	HICK ___	SICK ___	THICK ___	CHICK ___
48	LEAF ___	LEASE ___	LEASH ___	LEAK ___
49	CHEEK ___	CHEAP ___	CHEAT ___	CHIEF ___
50	RID ___	RIB ___	RIDGE ___	RIG ___

OVER

AUDITEC St. Louis, MO

APPENDIX B

SUBJECT CONSENT FORM

THE OHIO STATE UNIVERSITY

Department of Speech & Hearing Science

110 Pressey Hall
1070 Carmack Road
Columbus, OH 43210-1002

Phone 614-292-8207
FAX 614-292-7504

The Ohio State University Consent to Participate in Research

Study Title: The Post-Auricular Canal Hearing Aid: A Better Solution?

Researcher: **Stephanie Davidson Strang, Ph.D.**

Sponsor:

This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate.

Your participation is voluntary.

Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate. If you decide to participate, you will be asked to sign this form and will receive a copy of the form.

Purpose:

The purpose of this study is to compare typical advanced digital hearing aids with a new design of hearing aid, the post-auricular canal hearing aid, by SeboTek.

Procedures/Tasks:

At the first visit you will be given an audiological evaluation, and your performance with your current hearing aids will be measured with tests in the sound booth where you will be asked to repeat sentences heard in the presence of background noise and circle words heard in quiet from a group of choices. You will also be asked to fill out a questionnaire about listening with your current hearing aids.

At the second visit you will be fit with the study hearing aids (the SeboTek Post-Auricular Canal hearing aids) and instructed on their care and use. Measurements will be made with your current hearing aids and the study hearing aids by placing a probe

microphone tube in your ear canal and playing sound tones. You will also be asked to vocalize the "ee" vowel and measurements will again be made with each set of hearing aids. You will then be asked to wear the study hearing aids for 2 weeks.

At your third visit your performance with the study hearing aids will be measured with the same tests from the first visit. You will also be asked to fill out the questionnaire from the first visit, this time about listening with the study hearing aids.

Duration: Three sessions at 2 hours each, approximately 2 weeks apart.

You may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits:

There is the possibility of slight discomfort with ear canal placement of a thin flexible probe microphone tube used to measure your own voice. In the case that the tube brushes against your eardrum or causes any discomfort, you will be instructed to let us know immediately so that the tube can be repositioned. Again, there is no risk of injury, only slight discomfort. Other risks are minimal. However, sensitive and personal information concerning your hearing health will be asked. If you object to any of the above, you may withdraw from the study at any time.

You will be given the opportunity to try new "cutting edge" technology. This study may lead to improvements in clinical hearing aid evaluation and fitting methodologies.

Confidentiality: Clinical assessment data such as audiograms and case history information will be obtained from your patient chart at the Ohio State University Speech, Language & Hearing Clinic.

Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law. Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives:
You will receive $15 for each visit as well as $2 reimbursement for parking for each visit. If you decide to withdraw you will receive a pro-rated payment for the amount of time enrolled, at a rate of $3.75 for each 30 minute block of time completed. You will receive the $2 reimbursement for parking for each visit that you attend, even if you withdraw from the study.

Participant Rights:

You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status.

If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

Contacts and Questions:
For questions, concerns, or complaints about the study you may contact **the investigators at (614) 292-1802.**

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact **the investigators at (614) 292-1802.**

Signing the consent form

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this signed form.

Printed name of subject	Signature of subject
	AM/PM Date and time
Printed name of person authorized to consent for subject (when applicable)	Signature of person authorized to consent for subject (when applicable)
Relationship to the subject	AM/PM Date and time

Investigator/Research Staff

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A signed copy of this form has been given to the participant or his/her representative.

Printed name of person obtaining consent	Signature of person obtaining consent
	AM/PM Date and time

APPENDIX C

RECRUITMENT LETTER

THE OHIO STATE UNIVERSITY

Department of Speech and Hearing Science

Speech-Language-Hearing Clinic
141 Pressey Hall
1070 Carmack Road
Columbus, OH 43210-1002

Phone (614) 292-6251 (Voice/TDD)
Fax (614) 292-5723

2006

Dear_______________,

This letter is regarding a research study being conducted by Rebecca Bail and Claudia Dome - students at the Ohio State University. They are conducting a research study evaluating a new design of hearing aid, and are currently recruiting listeners to participate in the study. During this study, participants will be given the opportunity to try this new style of hearing aid, which fits discreetly behind the ear, is very comfortable and may provide improved performance in the presence of background noise. This product is designed for current or potential CIC or canal hearing aid wearers. You have been identified as a potential subject for this study.

If you agree to participate, you will be asked to wear a trial set of these hearing aids for two weeks. The study will require three visits to the clinic, each lasting two hours. During those visits you will be fit with the new style of hearing aid and measurements of performance will be made, both with your current hearing aids and with the trial set of hearing aids. The purpose of this project is clearly for research and not a promotion of a new product. By participating you would be given the opportunity to evaluate new technologies, but more importantly, your participation will improve our understanding of this new hearing aid design and will help us to better assess the potential benefits of this type of technology. You will also be compensated $15 for each visit, with $2 reimbursement for parking. Mrs. Dome or Ms. Bail will be contacting you by telephone to answer any questions you may have, but if you have any questions in the meantime, feel free to contact Ms. Bail at 614-507-6016, e-mail her at bail.4@osu.edu, or <u>call</u> me at 614-292-6251. I greatly appreciate your time and consideration.

Sincerely,

Gail M Whitelaw

Gail M. Whitelaw, Ph.D., Audiologist
Director, The Ohio State University Speech-Language-Hearing Clinic

APPENDIX D

ABBREVIATED PROFILE OF HEARING AID BENEFIT QUESTIONNAIRE

A

ABBREVIATED PROFILE OF HEARING AID BENEFIT

NAME: ______________________________ ☐ Male ☐ Female TODAY'S DATE: ___/___/___
Last First

INSTRUCTIONS: Please circle the answers that come closest to your everyday experience. Notice that each choice includes a percentage. You can use this to help you decide on your answer. For example, if a statement is true about 75% of the time, circle "C" for that item. If you have not experienced the situation we describe, try to think of a similar situation that you have been in and respond for that situation. If you have no idea, leave that item blank.

A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

	Own Hearing Aids	Research Hearing Aids
1. When I am in a crowded grocery store, talking with the cashier, I can follow the conversation.	A B C D E F G	A B C D E F G
2. I miss a lot of information when I'm listening to a lecture.	A B C D E F G	A B C D E F G
3. Unexpected sounds, like a smoke detector or alarm bell are uncomfortable.	A B C D E F G	A B C D E F G
4. I have difficulty hearing a conversation when I'm with one of my family at home.	A B C D E F G	A B C D E F G
5. I have trouble understanding the dialogue in a movie or at the theater.	A B C D E F G	A B C D E F G
6. When I am listening to the news on the car radio, and family members are talking, I have trouble hearing the news.	A B C D E F G	A B C D E F G
7. When I'm at the dinner table with several people, and am trying to have a conversation with one person, understanding speech is difficult.	A B C D E F G	A B C D E F G
8. Traffic noises are too loud.	A B C D E F G	A B C D E F G
9. When I am talking with someone across a large empty room, I understand the words.	A B C D E F G	A B C D E F G
10. When I am in a small office, interviewing or answering questions, I have difficulty following the conversation.	A B C D E F G	A B C D E F G
11. When I am in a theater watching a movie or play, and the people around me are whispering and rustling paper wrappers, I can still make out the dialogue.	A B C D E F G	A B C D E F G
12. When I am having a quiet conversation with a friend, I have difficulty understanding.	A B C D E F G	A B C D E F G

(Continued)

A Always (99%)
B Almost Always (87%)
C Generally (75%)
D Half-the-time (50%)
E Occasionally (25%)
F Seldom (12%)
G Never (1%)

	Own Hearing Aids	Research Hearing Aids
13. The sounds of running water, such as a toilet or shower, are uncomfortably loud.	A B C D E F G	A B C D E F G
14. When a speaker is addressing a small group, and everyone is listening quietly, I have to strain to understand.	A B C D E F G	A B C D E F G
15. When I'm in a quiet conversation with my doctor in an examination room, it is hard to follow the conversation.	A B C D E F G	A B C D E F G
16. I can understand conversations even when several people are talking.	A B C D E F G	A B C D E F G
17. The sounds of construction work are uncomfortably loud.	A B C D E F G	A B C D E F G
18. It's hard for me to understand what is being said at lectures or church services.	A B C D E F G	A B C D E F G
19. I can communicate with others when we are in a crowd.	A B C D E F G	A B C D E F G
20. The sound of a fire engine siren close by is so loud that I need to cover my ears.	A B C D E F G	A B C D E F G
21. I can follow the words of a sermon when listening to a religious service.	A B C D E F G	A B C D E F G
22. The sound of screeching tires is uncomfortably loud.	A B C D E F G	A B C D E F G
23. I have to ask people to repeat themselves in one-on-one conversation in a quiet room.	A B C D E F G	A B C D E F G
24. I have trouble understanding others when an air conditioner or fan is on.	A B C D E F G	A B C D E F G

Please fill out these additional items.

HEARING AID EXPERIENCE:	DAILY HEARING AID USE	DEGREE OF HEARING DIFFICULTY (without wearing a hearing aid):
☐ None	☐ None	☐ None
☐ Less than 6 weeks	☐ Less than 1 hour per day	☐ Mild
☐ 6 weeks to 11 months	☐ 1 to 4 hours per day	☐ Moderate
☐ 1 to 10 years	☐ 4 to 8 hours per day	☐ Moderately-Severe
☐ Over 10 years	☐ 8 to 16 hours per day	☐ Severe

HARL
Hearing Aid Research Lab

APPENDIX E

AUDIOMETRIC DATA

SUBJECT	EAR	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	WRT score	Type of Hearing Aid
1	right	30	30	55	75	85	NR	32%	CIC
	left	25	25	55	85	85	NR	44%	
2	right	35	35	40	40	45	65	58%	ITC
	left	40	50	45	50	55	65	38%	
3	right	60	75	75	65	60	75	8%	BTE
	left	45	45	40	30	50	NR	46%	
4	right	10	10	30	45	45	25	88%	CIC
	left	10	10	15	50	55	NR	80%	
5	right	50	55	65	65	65	65	26%	ITC
	left	20	50	65	65	65	NR	60%	
6	right	40	55	55	55	65	70	72%	ITC
	left	30	50	50	55	55	70	76%	
7	right	35	30	35	45	60	65	68%	ITC
	left	40	35	45	50	65	65	76%	
8	right	10	0	10	80	90	80	60%	CIC
	left	20	10	0	75	90	80	68%	
9	right	10	20	35	NR	NR	NR	50%	CIC
	left	0	15	35	95	95	NR	68%	
10	right	25	25	35	45	65	NR	84%	CIC
	left	30	35	55	80	95	NR	24%	

* Subject 3 had recently been fit with a BTE style hearing aid and had previously worn an ITC style hearing aid.

APPENDIX F

SAMPLE QUICK SPEECH-IN-NOISE LIST

TRACK 24
List 1

		Score
1. A white silk jacket goes with any shoes.	S/N 25	______
2. The child crawled into the dense grass.	S/N 20	______
3. Footprints showed the path he took up the beach.	S/N 15	______
4. A vent near the edge brought in fresh air.	S/N 10	______
5. It is a band of steel three inches wide.	S/N 5	______
6. The weight of the package was seen on the high scale.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 25
List 2

		Score
1. Tear a thin sheet from the yellow pad.	S/N 25	______
2. A cruise in warm waters in a sleek yacht is fun.	S/N 20	______
3. A streak of color ran down the left edge.	S/N 15	______
4. It was done before the boy could see it.	S/N 10	______
5. Crouch before you jump or miss the mark.	S/N 5	______
6. The square peg will settle in the round hole.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 26
List 3

		Score
Pitch the straw through the door of the stable.	S/N 25	______
_. The sink is the thing in which we pile dishes.	S/N 20	______
3. Post no bills on this office wall.	S/N 15	______
4. Dimes showered down from all sides.	S/N 10	______
5. Pick a card and slip it under the pack.	S/N 5	______
6. The store was jammed before the sale could start.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 27
List 4

		Score
1. The sense of smell is better than that of touch.	S/N 25	______
2. He picked up the dice for a second roll.	S/N 20	______
3. Drop the ashes on the worn old rug.	S/N 15	______
4. The couch cover and hall drapes were blue.	S/N 10	______
5. The stems of the tall glasses cracked and broke.	S/N 5	______
6. The cleat sank deeply into the soft turf.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 28
List 5

		Score
1. To have is better than to wait and hope.	S/N 25	______
2. The screen before the fire kept in the sparks.	S/N 20	______
3. Thick glasses helped him read the print.	S/N 15	______
4. The chair looked strong but had no bottom.	S/N 10	______
5. They told wild tales to frighten him.	S/N 5	______
A force equal to that would move the earth.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 29
List 6

		Score
1. The leaf drifts along with a slow spin.	S/N 25	______
2. The pencil was cut to be sharp at both ends.	S/N 20	______
3. Down that road is the way to the grain farmer.	S/N 15	______
4. The best method is to fix it in place with clips.	S/N 10	______
5. If you mumble your speech will be lost.	S/N 5	______
6. A toad and a frog are hard to tell apart.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 30
List 7

		Score
1. The kite dipped and swayed, but stayed aloft.	S/N 25	______
2. The beetle droned in the hot June sun.	S/N 20	______
3. The theft of the pearl pin was kept secret.	S/N 15	______
4. His wide grin earned many friends.	S/N 10	______
5. Hurdle the pit with the aid of a long pole.	S/N 5	______
6. Peep under the tent and see the clown.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 31
List 8

		Score
1. The sun came up to light the eastern sky.	S/N 25	______
2. The stale smell of old beer lingers.	S/N 20	______
3. The desk was firm on the shaky floor.	S/N 15	______
4. A list of names is carved around the base.	S/N 10	______
5. The news struck doubt into restless minds.	S/N 5	______
6. The sand drifts over the sill of the old house.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 32
List 9

		Score
1. Take shelter in this tent, but keep still.	S/N 25	______
2. The little tales they tell are false.	S/N 20	______
3. Press the pedal with your left foot.	S/N 15	______
4. The black trunk fell from the landing.	S/N 10	______
5. Cheap clothes are flashy but don't last.	S/N 5	______
6. At night the alarm roused him from a deep sleep.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

TRACK 33
List 10

		Score
1. Dots of light betrayed the black cat.	S/N 25	______
2. Put the chart on the mantel and tack it down.	S/N 20	______
3. The steady drip is worse than a drenching rain.	S/N 15	______
4. A flat pack takes less luggage space.	S/N 10	______
5. The gloss on top made it unfit to read.	S/N 5	______
6. Seven seals were stamped on great sheets.	S/N 0	______
25.5 - TOTAL =________ SNR Loss	TOTAL	______

APPENDIX G

ABBREVIATED PROFILE OF HEARING AID BENEFIT RESULTS

SUBJECT	Scores	EC Scale	BN Scale	RV Scale	AV Scale
1	Own Hearing Aid	25.00	47.83	70.67	58.17
	SeboTek Hearing aid	25.00	18.50	27.00	68.50
2	Own Hearing Aid	10.50	41.67	24.67	93.00
	SeboTek Hearing aid	1.00	16.83	28.25	28.83
3	Own Hearing Aid	4.67	29.17	37.33	39.50
	SeboTek Hearing aid	24.75	54.00	55.00	43.50
4	Own Hearing Aid	28.83	68.67	48.83	12.00
	SeboTek Hearing aid	10.17	24.67	29.60	8.33
5	Own Hearing Aid	29.17	78.83	74.83	66.50
	SeboTek Hearing aid	29.17	78.83	72.40	57.40
6	Own Hearing Aid	6.50	14.60	12.33	31.33
	SeboTek Hearing aid	27.33	24.80	33.33	4.67
7	Own Hearing Aid	22.50	18.50	18.50	10.17
	SeboTek Hearing aid	24.67	31.33	33.33	10.17
8	Own Hearing Aid	9.80	31.00	25.00	27.60
	SeboTek Hearing aid	9.25	31.25	25.00	57.20
9	Own Hearing Aid	35.17	72.67	70.67	74.67
	SeboTek Hearing aid	18.50	54.17	37.50	74.67
10	Own Hearing Aid	5.00	56.00	78.67	1.00
	SeboTek Hearing aid	37.67	64.17	71.50	53.00

APPENDIX H

CALIFORNIA CONSONANT TEST RESULTS

Subject	Score with Own Hearing Aid	Score with SeboTek Hearing Aid
1	56%	44%
2	46%	52%
3	74%	70%
4	90%	98%
5	54%	54%
6	72%	72%
7	100%	62%
8	58%	48%
9	40%	46%
10	62%	64%
Mean	65%	61%
Standard Deviation	19%	16%

APPENDIX I

QUICK SPEECH-IN-NOISE RESULTS

SUBJECT	Scores	Test 1	Test 2	Average
1	Own Hearing Aid	20.5	14.5	17.5
	SeboTek Hearing Aid	12.5	21.5	17.0
2	Own Hearing Aid	12.5	12.5	12.5
	SeboTek Hearing Aid	14.5	18.5	16.5
3	Own Hearing Aid	23.5	24.5	24.0
	SeboTek Hearing Aid	10.5	8.5	9.5
4	Own Hearing Aid	15.5	7.5	11.5
	SeboTek Hearing Aid	6.5	10.5	8.5
5	Own Hearing Aid	15.5	23.5	19.5
	SeboTek Hearing Aid	25.5	25.5	25.5
6	Own Hearing Aid	18.5	20.5	19.5
	SeboTek Hearing Aid	21.5	24.5	23.0
7	Own Hearing Aid	7.5	8.5	8.0
	SeboTek Hearing Aid	19.5	13.5	16.5
8	Own Hearing Aid	15.5	16.5	16.0
	SeboTek Hearing Aid	13.5	13.5	13.5
9	Own Hearing Aid	25.5	25.5	25.5
	SeboTek Hearing Aid	21.5	20.5	21.0
10	Own Hearing Aid	10.5	4.5	7.5
	SeboTek Hearing Aid	2.5	5.5	4.0

Mean Own Hearing Aid	16.15
Standard Deviation Own Hearing Aid	6.23
Mean SeboTek Hearing Aid	15.50
Standard Deviation SeboTek Hearing Aid	6.77

APPENDIX J

OCCLUSION EFFECT RESULTS

SUBJECT	EAR	Own Hearing Aid	SeboTek Hearing Aid
1	right	10.0	7.0
	left	21.0	14.0
2	right	5.0	3.0
	left	1.5	0.5
3	right	NA	NA
	left	2.5	5.5
4	right	13.5	3.5
	left	11.5	8.0
5	right	21.5	15.0
	left	8.0	4.5
6	right	14.0	1.0
	left	4.5	-4.0
7	right	10.0	4.0
	left	6.0	-16.0
8	right	7.0	26.5
	left	-5.0	6.0
9	right	9.5	-1.5
	left	12.0	2.5
10	right	16.5	-10.5
	left	19.5	10.0
Mean		9.90	4.20
Standard Deviation		6.90	9.20

APPENDIX K

PROBE MICROPHONE MEASURES OF GAIN RESULTS

Subject	SeboTek Hearing Aid	Own Hearing Aid
1	81	82
2	77	82
3	72	68
4	78	83
5	72	83
6	70	80
7	78	88
8	71	77
9	61	70
10	78	70
Mean	73.70	78.30
Standard Deviation	5.89	6.67

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